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I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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1/77

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P01/7700 0.00-0402214.1 NONE

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
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South Wales
NP10 8QQ

1. Your reference — GAS / VAPOUR

2. Patent application number *(The Patent Office will fill this part in)* — 0402214.1 — 31 JAN 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — MR DONALD STUART MILLER, BROOKSIDE, CHURCH WALK, HARROLD, BEDFORD, MK43 7DG

   Patents ADP number *(if you know it)* — 0121621700

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

   ABRASIVE IN GAS/VAPOUR ENTRAINMENT

5. Name of your agent *(if you have one)* — J M Gregory & Co

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — 26 Cyril Street, Northampton, NN1 5EL

   Patents ADP number *(if you know it)*

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
	—	

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*
—	

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — NO

   Answer YES if:

   a) any applicant named in part 3 is not an inventor, or

   b) there is an inventor who is not named as an applicant, or

   c) any named applicant is a corporate body.

   Otherwise answer NO (See note d)

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	
Description	3
Claim(s)	
Abstract	
Drawing(s)	1

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/We request the grant of a patent on the basis of this application.

Signature(s) [signature]

Date 30 Jan 04

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

DON MILLER
01234 721089

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

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d) If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) Part 7 should only be completed when a divisional application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entitlement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlier UK application, you should also complete part 6 with the priority details.

Abrasive in Gas/Vapour Entrainment

The present invention relates to the entrainment of abrasive particle/gas/vapour mixtures into high velocity liquid jets and the condensation of the vapour to produce abrasive/gas/liquid cutting jets. Normally, but not exclusively, the liquid is water, the gas is air, the vapour is steam and the abrasive a powder such as garnet or aluminium oxide.

More effective abrasive waterjet cutting heads are needed to meet market demands for faster cutting, greater cut surface area generation per kilogram of abrasive and smaller diameter cutting jets to enable finer detail to be reproduced.

Abrasive in air entrainment is the established method of generating abrasive waterjets for precision machining. Water at ultra high pressures of 3000 to 4000bar is passed through a sharp edged orifice to generate a jet moving at over 700m/s. The water jet traverses a chamber to entrain air that conveys abrasive particles into the chamber. The waterjet along with the air and abrasive leave the chamber via a ceramic mixing nozzle that is aligned along the axis of the waterjet orifice. In the nozzle momentum is transferred from the water to the initially slow moving abrasive particles. Abrasive/water/air mixtures leave nozzles as focused cutting jets and impact on work pieces to produce cuts.

Cutting heads operate at sub-atmospheric pressures resulting in air densities being over 5000 times less than that of the abrasive particles. Air is readily accelerated by water jets to enter nozzles at sonic velocities but air drag on abrasive particles is ineffectual in accelerating and in aligning particles to waterjets. The result is poor energy transfer from waterjets to abrasive particles and high rates of nozzle wear.

The method of generating abrasive waterjets described in this application involves conveying abrasive particles to cutting heads using mixtures of air and steam. The steam is subsequently condensed to one thousandth or so of its volume. As the steam condenses it drags particles into waterjets. The condensed water typically amounts to less than 1%wt of the waterjet mass flow so its acceleration by waterjets does not greatly reduce the energy available for accelerating abrasive particles.

Steam condensation is a powerful mechanism for generating flows to carry abrasive particles to cutting heads. Small diameter waterjets that would not entrain sufficient air to convey abrasive particles can condense sufficient steam to convey abrasive. Cutting heads that utilise abrasive in steam entrainment can operate with nozzle diameters below 200μm, compared to over 300μm for abrasive in air entrainment.

According to the first aspect of the present invention there is provided a method of entrainment of abrasive particles into high velocity liquid jets to give abrasive cutting jets, the method comprises the step of providing pressurised liquid to a restriction to form a high velocity liquid jet, a metered supply of abrasive particles in a gas, a source of vapour that is condensed by the liquid jet and conduit means through which gas/vapour flow carries said abrasive particles to be entrained into the said liquid jet

The liquid is preferably water

The vapour is preferably dry steam

The gas is preferably air

The abrasive is preferably garnet, olivine or aluminium oxide

The abrasive may be heated to above the condensation temperature of the steam

According to a second aspect of the present invention, there is provided apparatus to generate an abrasive cutting jet, the apparatus comprising a pressurised water supply and a orifice to form a waterjet, an abrasive particle entry chamber and a nozzle in which a suspension of abrasive particles in air/steam is entrained and the steam condensed and momentum exchanged between the high velocity waterjet and abrasive particles.

The waterjet orifice may form part of the load bearing structure of a cutting head.

Preferably the ratio of nozzle to waterjet orifice diameters are between 1.5 and 2.5

The nozzle may comprise a transition zone of diameter progressively decreasing from an abrasive entry chamber to a near parallel bore.

Nozzles may consist of two or more sections with transitions between sections to smaller bores in second and subsequent sections.

The abrasive mixture entry chamber may be lined or constructed from low thermal conductivity material.

According to a third aspect of the present invention, there is provided a means of generating and feeding steam to the said apparatus.

Preferably the steam is generated using electric heating.

Preferably the electric heating is by positive temperature coefficient heaters

According to a forth aspect of the present invention, there is provided a means of metering abrasive to the said apparatus.

According to the fifth aspect of the present invention, there is provided a means of directing the abrasive/water/air flow from said nozzle of said apparatus onto work pieces.

The design of abrasive in air/steam cutting heads and their abrasive feed systems are described with reference to:

Figure 1 shows an abrasive in air/steam cutting head
Figure 2 shows a flow circuit for feeding abrasive to abrasive in air/steam cutting heads

Referring to Figure 1, pressurised water enters a cutting head 7 through conduit 1. The water passes through orifice 6 to form a jet that traverses mixing chamber 8 and into the nozzle 4.

Air/steam carrying abrasive particles enters the cutting head 7 through conduit 2 to chamber 8, which connects to a transition region 5 to the bore 9 of nozzle 4. Entrainment and axial acceleration of the abrasive particles and condensation of steam takes place in chamber 8 and transition 5 with the most of the momentum exchange between water and abrasive occurring in the nozzle bore 9. Abrasive/water/air mixtures leave the bore 9 of nozzle 4 as a cutting jet 3. Typically the ratios of diameters of nozzles 9 to orifice 6 are 1.5 to 2.5.

The mixing tube 4 may be manufactured from polycrystalline diamond or other form of diamond.

Connection 2 and chamber 8 may be lined with or constructed from low thermal conductivity, abrasive resistance materials.

It is desirable for the outlet from orifice 6 to be within a few water jet diameters of the inlet to the transition region 5 of nozzle 4 and this may require orifice 6 to form part of the structure resisting fluid pressure loads. These loads may exceed 400N per square millimetre. Sharp edged orifices are essential for the satisfactory operation of abrasive in air cutting heads but they are easily damaged by contaminants in the water flow and they have limited lives. It is therefore advantageous not to use a sharp edged orifice for nozzle 6 and this is practical because of the short distance between orifice 6 and nozzle transition region 5. A shaped bore for orifice 6 is preferably machined in a diamond blank that is attached to and forms part of the pressure retaining structure of cutting head 7.

Figure 2 shows a flow circuit for feeding abrasive to cutting heads such as shown in Figure 1. Abrasive particles with air flow out of vessel 21 flow via conduit 22, metering device 23 and conduit 24 to junction 25 where the particles and air are mixed with steam flow from steam generator 27 flowing along conduit 26 to junction 25. From junction 25 the abrasive is carried through conduit 2 by steam/air flow and into cutting head 7. Abrasive in vessel 21 may be heated to prevent condensation on the particles whilst flowing to cutting head 7 and the abrasive particles in vessel 21 may be blanked in steam to prevent air reaching the cutting head 7.

Provision may be made for trace heating of all components and conduits in the feed circuit of Figure 2 and for pre warming of the circuit and flow surfaces in cutting head 7 before abrasive flow is commenced to cutting head 7.

Junction 25 may take the form of an educator with an inlet nozzle size that enables pressures in the steam generator 27 and passage 26 to be maintained above atmospheric pressure and/or provide the driving mechanism to induce abrasive flow through metering device 23. The driving steam may pass down through the abrasive feed vessel to assist in metering abrasive out of the vessel.

Steam generator 27 is preferably electric powered. A power input of less than 1kW is sufficient to provide steam for abrasive flows up to 0.5kg per minute but higher power inputs may be used particularly for warming up the flow circuit prior to starting abrasive flow. The steam may be superheated in the steam generator or after the generator.

Positive temperature coefficient heaters may be used to limit temperatures and pressures. Steam conditions may be restricted to 3 bar and 150 C temperature to allow engineering plastics to be used for tubes and components.

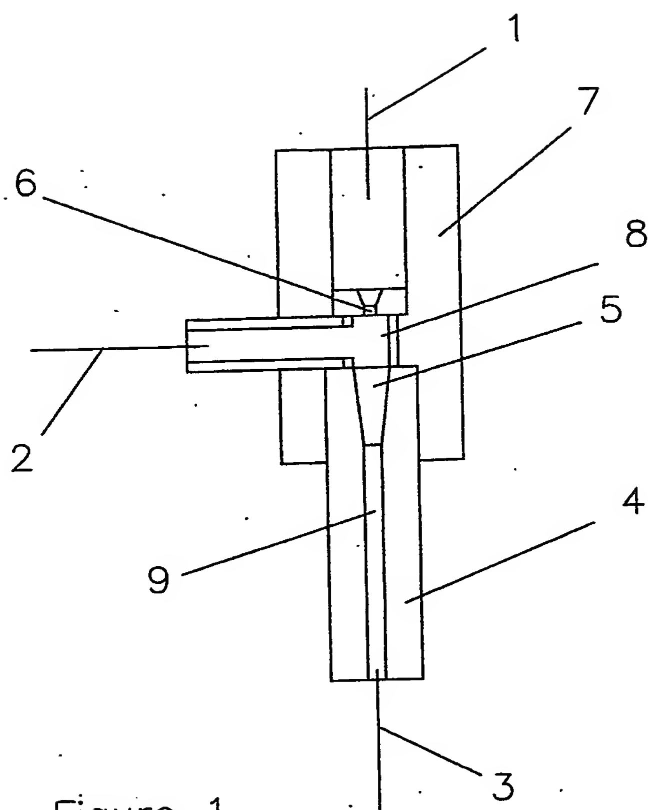

Figure 1

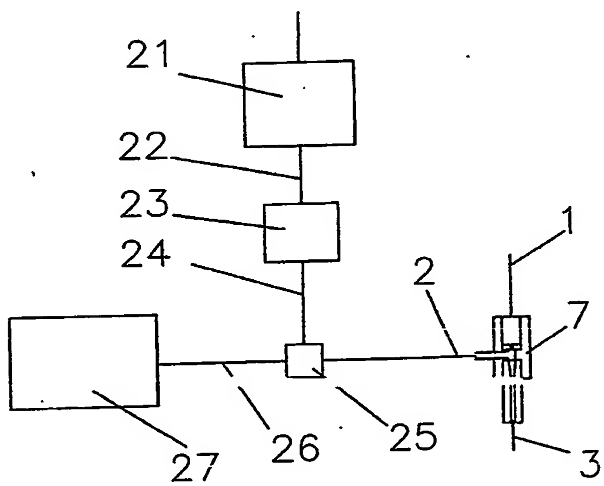

Figure 2

Document made available under the Patent Cooperation Treaty (PCT)

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